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Joint ICTP/IAEA Advanced School on Dosimetry in Diagnostic Radiology and its Clinical Implementation

11 - 15 May 2009

Dosimetry for CT (1): Basic Dosimetry

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And its Clinical Implementation
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Dosimetry for CT (1)
Basic Dosimetry

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Reminder

- Rotating fan-beam of X-rays
- 3d imaging
- High dose to patient
- Increasing number of applications

CT terminology I

- Axial scanning
  - 1 rotation of beam followed by stepwise couch movement
- Helical/spiral scanning
  - Continuous table movement & beam rotation

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CT terminology II

- Increment – distance moved by couch (axial scanning)
- Nominal (or irradiated) slice width – selected width of X-ray beam / detectors used
- Reconstructed slice width – slice width used for 3d image reconstruction
- Pitch – table movement relative to nominal slice width (helical scanning)

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Computed Tomography Dose Index

- Applies to single axial scan only
- Dose measured on axis of scanner using pencil ionisation chamber

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Computed Tomography Dose Index

- Applies to single axial scan only
- Measured on axis of scanner using pencil ionisation chamber
- Calculated as integral of air kerma along chamber divided by nominal slice thickness
- Several different versions!!

Dose quantities used

- $C_{a,100}$ – measured in air, integrated over 100mm
- C_w – weighted value of central & peripheral values in PMMA phantom
- ${}_nC_{a,100}/{}_nC_w$ – normalized to unit tube current-time product
- C_{vol} – takes account of helical pitch or axial scan spacing

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Phantoms for CT dosimetry

- Cylindrical PMMA phantoms with holes for pencil chamber
- 32 cm body phantom
- 16 cm head phantom

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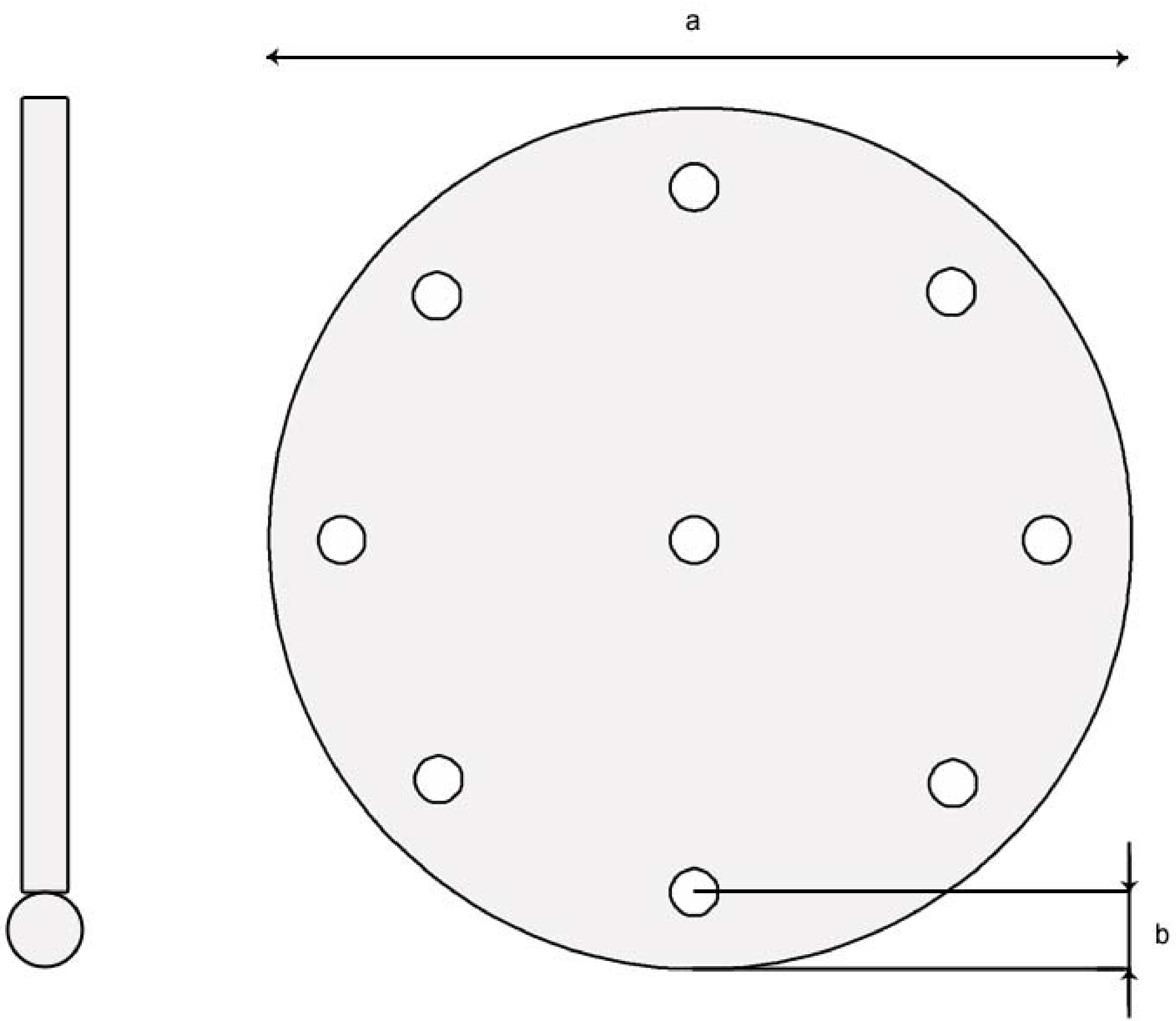

Material : PMMA

Head phantom

a = 160 mm
b = 10 mm

Body phantom

a = 320 mm
b = 10 mm

Equipment for CT measurements

- CT ionization chamber and electrometer calibrated for CT beam qualities
- Chamber support stand
- Thermometer & barometer
- CT head & body phantoms

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Methodology for CT measurements in air

- Position chamber in stand so beyond couch
- Adjust couch position so chamber along axis of scanner and beam centred at central point of chamber
- Record 3 dose measurements for single axial scan at selected parameters (no couch movement)
- Record all data + temperature & pressure

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Data to record

- Tube voltage
- Beam filter
- Tube loading (tube current & rotation time)
- Nominal slice width
- Measure for all clinical tube voltage / filter / slice widths

Methodology for CT measurements in phantoms

- Position phantom on couch (use head rest if appropriate)
- Position chamber in central position in phantom
- Adjust couch position so chamber centred as before
- Record 3 dose measurements for single axial scan at selected parameters (no couch movement)
- Record all data + temperature & pressure
- Repeat for peripheral positions (north, south, east & west)

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Calculation of $C_{a,100}$

$$C_{a,100} = \frac{1}{NT} \overline{M} \, N_{P_{KL},Q_0} k_Q k_{TP}$$

$\overline{M}$: mean value of dosimeter readings

k_{TP} : correction factor for temperature and pressure

$N_{P_{KL},Qo}$: dosimeter calibration coefficient

k_Q : beam quality correction factor

NT : nominal width of irradiating beam

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Normalized $C_{a,100}$

$$ {}_{n}C_{\mathrm{a},100} = \frac{C_{\mathrm{a},100}}{P_{\mathrm{It}}} $$

P_{It} : tube loading for 1 complete rotation

Values vary with tube voltage

Some variation with nominal slice width

May vary with beam filter

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Calculation of C_w

$$C_{\mathrm{PMMA,100,c}} = \frac{1}{NT} \overline{M}_{\mathrm{c}} \, N_{P_{\mathrm{KL}},Q_0} k_Q \, k_{\mathrm{TP}}$$

$$C_{\mathrm{PMMA,100,p}} = \frac{1}{NT} \overline{M}_{\mathrm{p}} \, N_{P_{\mathrm{KL}},Q_0} k_Q \, k_{\mathrm{TP}}$$

$$C_{\mathrm{W}} = \frac{1}{3}\left(C_{\mathrm{PMMA,100,c}} + 2 \, C_{\mathrm{PMMA,100,p}}\right)$$

$${}_{\mathrm{n}}C_{\mathrm{W}} = \frac{C_{\mathrm{W}}}{P_{\mathrm{It}}}$$

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Sources of uncertainty

- Measurement scenario
- Precision of reading
- Precision of tube loading indicator
- Precision of chamber & phantom positioning
- Phantom construction
- Chamber response in phantoms

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Typical uncertainties

$C_{a,100}$: 6 – 13%

C_w : 8 – 14%

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Patient dosimetry

- Patient dose assessed in terms of
  - C_{vol}
  - $P_{KL,CT}$
- Derived from phantom measurements & patient scan parameters
- No direct measurements on patients
- Collect technique data for at least 10 patients (restricted size range)

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Data to be collected for each patient

- Tube voltage;
- Beam filter type;
- Slice thickness;
- Use of tube current modulation techniques;
- Couch movement between axial rotations or per helical rotation;
- For each axial scan series in the examination procedure: the total tube loading for the scan series (might be obtained from the tube loading(s) for each axial rotation);
- For each helical scan series in the examination procedure: the total tube loading for the series (might be obtained from the average tube current and total scan time).

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Calculation of dose quantities for a series of specific patient examinations I

- For the given patient examination divide the procedure into one or more axial and/or helical scan sequences obtained with the same scan settings
- For each scan sequence obtain the measured value of ${}_{n}C_{W}$ for the recorded patient exposure conditions, selecting measurements obtained with the head or body phantom as appropriate

$$ {}_{\mathrm{n}}C_{\mathrm{VOL}} = {}_{\mathrm{n}}C_{W} \frac{NT}{l} $$

N is the number of simultaneously obtained tomographic slices
T the nominal slice thickness
l is the distance moved by the couch per scanner rotation

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Calculation of dose quantities for a series of specific patient examinations II

Calculation of C_{vol}

$C_{VOL} = {}_{n}C_{VOL}\ P_{IT}$ P_{IT} is mAs / rotation for scan

$C_{VOL} = {}_{n}C_{w}\ P_{IT}$ P_{IT} is effective mAs / slice for scan

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Calculation of dose quantities for a series of specific patient examinations III

$$P_{KL,CT} = l \; {}_{n}C_{VOL} \; P_{ITtot}$$

l is the distance moved by the couch per scanner rotation

P_{ITtot} total mAs/scan
(= mA x total scan time)

NB Units mGy cm

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Calculation of dose quantities for a series of specific patient examinations IV

- The air kerma-length product for the complete examination is obtained by adding together the contributions from the individual scan sequences
- Using the results from all patients in the sample, calculate the mean value of the CT air kerma-length product for the complete examination

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Sources of uncertainty

- Measurement scenario
- Uncertainty in measurement of ${}_{n}C_{w}$
- Precision of tube loading indicator
- Whether or not displayed quantities include any mA modulation

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Typical uncertainties

$P_{KL,CT}$: 9 -15%